

EVALUATING THE IMPACT OF AIR INFILTRATIONS ON THE THERMAL AND ENERGY PERFORMANCES FOR DIFFERENT TYPES OF DWELLINGS IN CASABLANCA CITY

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ABSTRACT

Improving the energy and thermal performances of buildings involves studying all the internal and external factors that can affect them. These factors include air infiltration that can occur through the building envelope. In order to meet the requirements of their thermal regulations, the measurement of infiltration become a common practice in some European and North American countries. Although this practice is still very rare in Morocco even not applied. In order to estimate the impact of air infiltration on the energy consumption of the Moroccan residential sector, we have carried out measurements using pressurization by blower door in four houses located in Casablanca with different standings and characteristics. The dynamic modelling of houses with measured leakage rates allow us to quantify the thermal losses due to infiltration and the corresponding energy impact. The dynamic modelling results show that the interior temperatures of the four houses are negatively impacted by up to 3.5 degrees and that the additional energy cost reaches up to 26% of the winter electricity consumption.

KEYWORDS: *Infiltrations, Building, Thermal Losses, Energy, Performance & Dynamic Modelling*

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1. INTRODUCTION

The thermal and energy performance of buildings are dependent on a large number of external and internal factors [1-2]. Studies conducted in recent years on air infiltration that can be caused by wind force and stack effect, have shown that the impact of thermal and energy performance is not negligible [3-5]: They can represent 25 to 50% of thermal loads in residential and commercial buildings [6]. In France, infiltration losses represent 15% of additional energy consumption in winter [7]. In the USA, a study concludes that infiltrations are responsible for 33 % of the heating loads in office buildings [8].

Knowing of the air permeability of building problems, several countries have decided to take into account air infiltrations in energy performance calculation procedures and have defined the standards of measures and regulatory values that should be satisfied [9].

In the absence of sectorial studies on the subject of infiltrations and requirements in Moroccan thermal regulation [10], we wanted to study the impact of air infiltrations on energy consumption for four residential houses in Casablanca. The infiltration airflow rate of differential pressure were first determined by the

pressurization/ depressurization technique by blower door.

The measurement results allowed us to obtain the infiltration airflow rate. They are then integrated in a dynamic modelling to quantify the thermal losses due to the infiltrations during a winter period, taking into account all the internal and external parameters that can affect them. The thermal and energy performances corresponding to the measured leakage rates are compared with those that the houses should have if the airflow rates comply with the requirements of the French thermal regulation [11] chosen as an example of a comparison reference.

2. MATHEMATICAL MODEL

The distribution of the wind pressure on a facade of a building is expressed as follows [12]:

$$P_w = C_p^{1/2} \rho_{out} U^2 \quad (1)$$

C_p : Coefficient of wind pressure.

ρ : Density of the outside air in Kg/m^3 .

U : Wind speed in m/s which is calculated as follows:

$$U(h) = U_m k \left(\frac{h}{h_m} \right)^n \quad (2)$$

$U(h)$: Wind speed at height h .

U_m : Wind speed at the weather local station.

h : Height from the ground.

h_m : Local station height.

k and n are the coefficients depending on the location and neighbourhood of the building.

The infiltration rate through the openings in the building envelope can be described according to the formula [13]

$$Q = c(\Delta P)^n \quad (3)$$

Q : Leakage rate in m^3/s .

c : Leakage coefficient.

n : Pressure exponent.

The stack induced airflow Q_s and wind-induced airflow Q_w are defined as [13]:

$$Q_w = c C_w (sU)^n \quad (4)$$

$$Q_s = c C_s (\Delta T)^n \quad (5)$$

S is a factor depending on the presence or absence of obstacles to the winds near the house.

C_w : Wind coefficient $(L/s)^2/(cm^4 \cdot (m/s)^2)$

C_s : Thermal draft coefficient $(L/s)^2/(cm^4 \cdot K)$

U : The wind speed (m/s)

ΔT : The average indoor-outdoor temperature difference (K).

A technical superposition made by Sherman, Walker, and Wilson (1992) allows us to write leak flow according to equation:

$$Q = \sqrt{Q_s^2 + Q_w^2} \quad (6)$$

The energy consumption required for the sensible heating or cooling of this leakage flow is calculated according to the equation bellow [13]:

$$PS = Q\rho C_p \Delta T \quad (7)$$

ρ : Air density (kg/m^3)

C_p : Specific heat of air $(J/(kg \cdot K))$.

3. MEASUREMENTS AND MODELIZATION

3.1 Measurement technique

Measurements of the buildings infiltrations are usually achieved via the pressurization/depressurization technique by blower door. The blower door consists of a waterproof canvas connected to a calibrated fan which is placed on an outer opening (door, window) Figure 2. The test is carried out according to standards such as European standard EN 13829 which describing the methodology for carrying out pressurization measurements [14]. All the air intakes and openings that normally contribute to the ventilation of the building are condemned so as to leave only the air from leakages. Static pressure taps are placed inside and outside the housing. Everything is connected to a computer that records the pressure measurements and the corresponding fan flow.

3.2 Cases Studied

The measurements of infiltration by blower door was carried out for four houses with different characteristics (surface, year of construction, type of heating used...etc.).

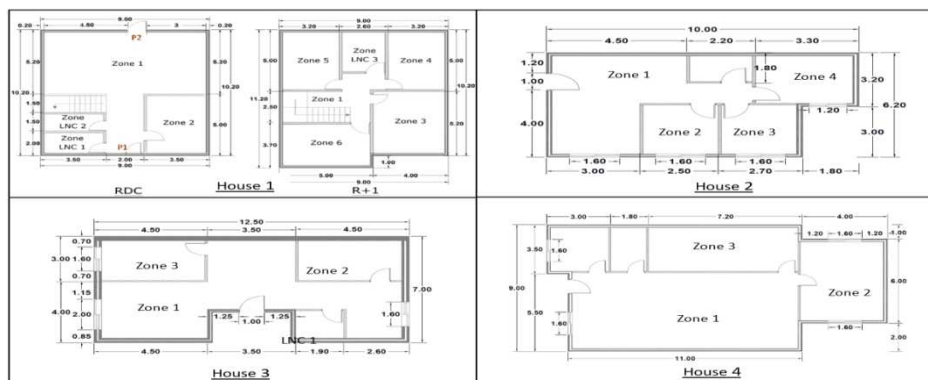
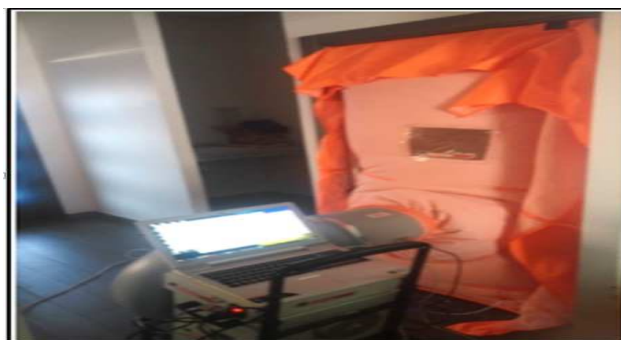


Figure 1: The Houses Plans

Table 1: The Houses Characteristics

Dwellings	Floor Surface (m ²)	Construction Year	Standing	Area of Windows and Door (m ²)	Position of Neighbors	Type of Heating	Average Monthly Electric Consumption
House 1	180	2013	Height standing	31,5	No Neighbours	Air Conditioner	450 KWh
House 2	121	2002	Average standing	12,6	all sides	Electric heater	320 KWh
House 3	80	1998	Average standing	10,2	all sides	Electric heater	250 KWh
House 4	55	2011	Social Housing	12	all sides	Electric heater	190 KWh

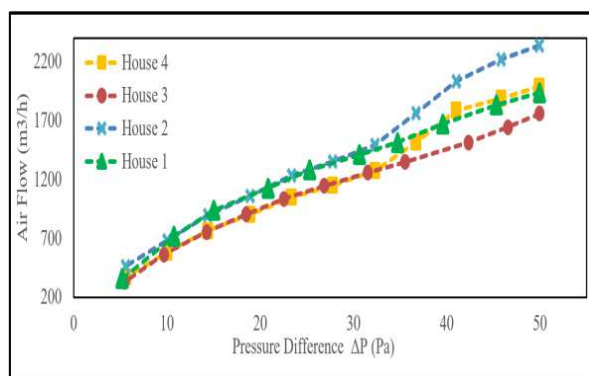
The fan door used generate an airflow up to 4400 3/h à 50Pa

**Figure 2: The Used Blower Door Performances****Table 2: Characteristics of The Blower Door Used**

Max Flow rate range	70à 4400 m3/h à 50 Pa
Differential pressure sensor	Precision : +/- 1%
Hot wire sensor for flow measurement	From 0 to 3 m/s : +/- 0,03 m/s
	From 3 to 20 m/s : +/- 0,01 m/s
Acquisition rate	30 mesures per second
Door dimensions	Width 0,6 to 1,2m
	Height 1,3 to 2,4m

Measurements

The blower door is installed and the Infiltrations airflow rates are read at differential pressures inside/outside from 5Pa to 50Pa.

**Figure 3: The houses Airflow Leaks According Pressure Differences**

From Equation 1, we write:

$$\ln(Q) = \ln(c) + n \cdot \ln(\Delta P) \quad (8)$$

The values of c and n are determined by linear regression.

Placing the blower door in an opening n°1 (door or window) inhibits its leakages, because the frame and the cover of the blower door makes it leak-proof.

The measured leakage rate is therefore:

$$Q_{1\text{measured}} = Q_T - Q_1 \quad (9)$$

Q_T is the total leakage airflow of the house

Q_1 the leakage airflow of the opening n°1.

In order to take into account the leakage airflow of the opening n°1, we have proceed to eliminate the leakages of another opening n°2 (door or window) with a special seals after using a thermal camera to detect leakages zones (Figure 3).

Then, the test is renewed (blower door always in the door n°1).

The measured leakage rate is:

$$Q_{2\text{measured}} = Q_T - Q_1 - Q_2 \quad (10)$$

Q_2 is the leakage airflow rate of the opening n°2 (door or window).

Then, the blower door is installed at the opening n°2 and the test is renewed.

The measured leakage airflow rate is:

$$Q_{3\text{measured}} = Q_T - Q_2 \quad (11)$$

This method provides the total leakage airflow:

$$Q_T = Q_{1\text{measured}} - Q_{2\text{measured}} + Q_{3\text{measured}} \quad (12)$$

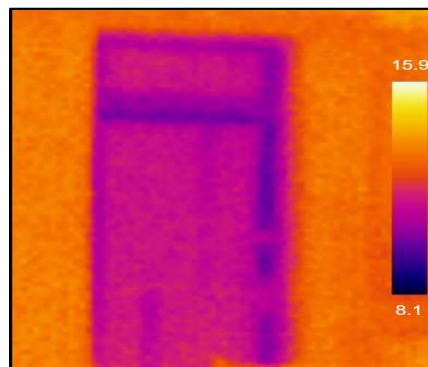


Figure 4: The Use of a Thermal Camera for the Detection of Air Leaks (around the Door Frame - Purple Color)

The leaks and coefficients values of the four houses are indicated below:

Table 3: Values of c, n, Q4Pa, n50 and AL of Houses

House	c	n	Q4Pa (m ³ /h.m ²)	n50 (vol/h)	AL (cm ²)
House 1	165,49	0,63	1,98	4,23	642
House 2	111,2	0,77	2,7	6,32	581,13
House 3	35,83	1,07	1,97	9,81	283,14
House 4	94,52	0,77	5,01	11,72	493,96

Dynamic Modelling

The dynamic modelling was carried out with Deisgn Builder Version 5.0.10.016 which integrates Energy plus calculation engine.

The 4 dwellings were modelled by specifying the following elements:

- The weather file of the city of Casablanca
- The dimensions and material characteristics of walls, floors, doors and windows.
- The dimensional characteristics of neighbourhood buildings and obstacles.
- The housing occupation scenarios
- The heating system used
- Infiltration rates (measured and required)

Two simulation cases were made:

- The infiltration airflow rate is based on the results obtained from the pressurization test.
- The infiltration airflow rate used is the airflow rate Q4Pa values required by the French thermal regulation: 0,6 m³/h. m² for the individual houses and 1 m³/h. m² for collectives houses.

4. RESULTS AND DISCUSSIONS

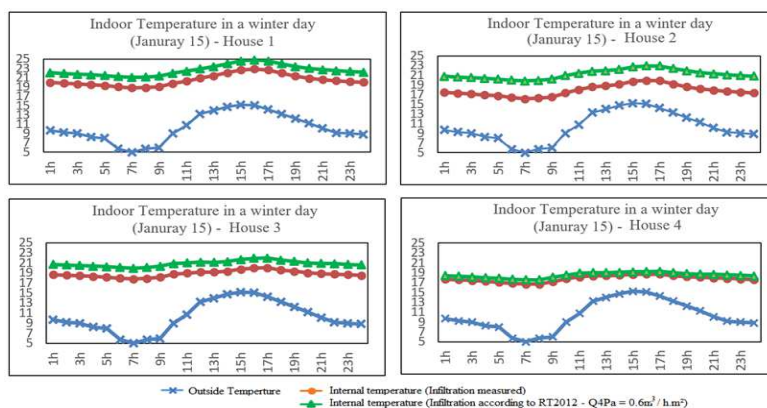


Figure 5: Evolution of Indoor Temperature in a Winter Day (January 15)

Dynamic simulation on a winter day (January 15) gives different temperature values depending on the infiltration airflow rates used (air flow rate measured by the pressurization test or the airflow rate required by the French thermal regulation RT2012 chosen as the reference of comparison.).

The outside temperature during the day varies from 5°C to 15°C (from the weather file of Casablanca).

The house 1 is well thermally isolated; its indoor temperature varies from 21°C to 25°C if the infiltrations airflow complies with the infiltration airflow rate required by the thermal regulation. Taking into account the measured infiltrations airflow, it varies from 19°C to 23°C.

For house 2, the temperature drop due to excessive infiltrations is about 3.5°C.

For house 3, the temperature drop due to excessive infiltrations is about 2°C.

The maximum temperatures in winter taking into account the infiltrations measured for the houses 1, 2 and 3 don't exceed 20 ° C which justifies the use of electric heater winter.

House 4 is a poorly isolated social house, the temperature does not exceed 19 ° C even respecting the infiltration rate required and the impact of infiltrations is reduced.

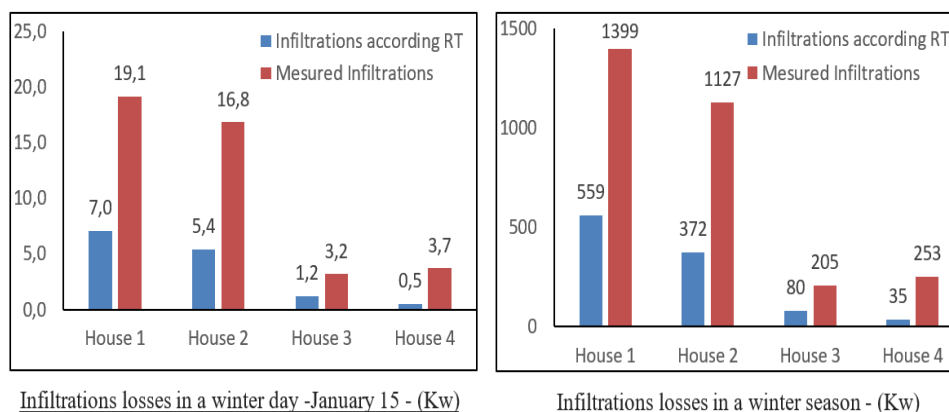


Figure 6: Infiltrations Losses in a Winter Day and Winter Season

The thermal losses corresponding to the infiltrations measured for the four houses are from 2.6 to 7.4 times the losses that would result from infiltrations complying with the requirement of RT 2012.

The impact on energy consumption is not negligible for houses 2, 3 and 4 using electric heaters for heating (for a net operating time of 8 hours per day).

The extra cost of electricity consumption due to excessive infiltrations in winter is 26.2% for house 2, 5.5% for house 3 and 12.7% for house 4. For the house 1 using a reversible air-conditioner having a performance coefficient of 3.6, the additional power consumption is 7.6%.

5. CONCLUSIONS

In this work, we studied the impact of air infiltrations on the thermal and energy performance of four houses in Casablanca.

The infiltration measurements carried out have shown that the leak rates measured are very high: up to 7 times the flow rate required by the French thermal regulations used as a reference for comparison.

For the dwellings studied, the infiltrations have a negative impact on indoor temperatures up to 3.5°C.

Exceeding the required values of infiltration rates represents an additional energy cost of 5.5 to 26.2%.

The realization of sectorial studies on a large sample of houses of different types and standing, located in different geographical zones with various climatic zones, will give a more precise and representative result of the infiltrations impact on the energy performance of the residential sector in Morocco.

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